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Accreting millisecond pulsar SAX J1808.4-3658 during its 2002 outburst: Evidence for a receding disc

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Abstract

An outburst of the accreting X-ray millisecond pulsar SAX J1808.4-3658 in 2002 October-November was followed by the Rossi X-ray Timing Explorer for more than a month. A detailed analysis of this unprecedented data set is presented. For the first time, we demonstrate how the area covered by the hotspot at the neutron star surface is decreasing in the course of the outburst together with the reflection amplitude. These trends are in agreement with the natural scenario, where the disc inner edge is receding from the neutron star as the mass accretion rate drops. These findings are further supported by the variations of the pulse profiles, which clearly show the presence of the secondary maximum at the late stages of the outburst after October 29. This fact can be interpreted as the disc receding sufficiently far from the neutron star to open the view of the lower magnetic pole. In that case, the disc inner radius can be estimated. Assuming that disc is truncated at the Alfvén radius, we constrain the stellar magnetic moment to $\mu = (9 \pm 5) \times 1025$ G cm3, which corresponds to the surface field of about 108 G. On the other hand, using the magnetic moment recently obtained from the observed pulsar spin-down rate we show that the disc edge has to be within factor of 2 of the Alfvén radius, putting interesting constraints on the models of the disc-magnetosphere interaction. We also demonstrate that the sharp changes in the phase of the fundamental are intimately related to the variations of the pulse profile, which we associate with the varying obscuration of the antipodal spot. Using the phase-resolved spectra, we further argue that the strong dependence of the pulse profiles on photon energy and the observed soft time lags result from the different phase dependence of the normalizations of the two spectral components, the blackbody and the Comptonized tail, being consistent with the model, where these components have significantly different angular emission patterns. The pulse profile amplitude allows us to estimate the colatitude of the hotspot centroid to be ~4°-10°. © 2009 RAS.

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Keywords

Accretion, accretion discs, Methods: Data analysis, Pulsars: Individual: SAX J1808.4-3658, Stars: Neutron, X-rays: Binaries